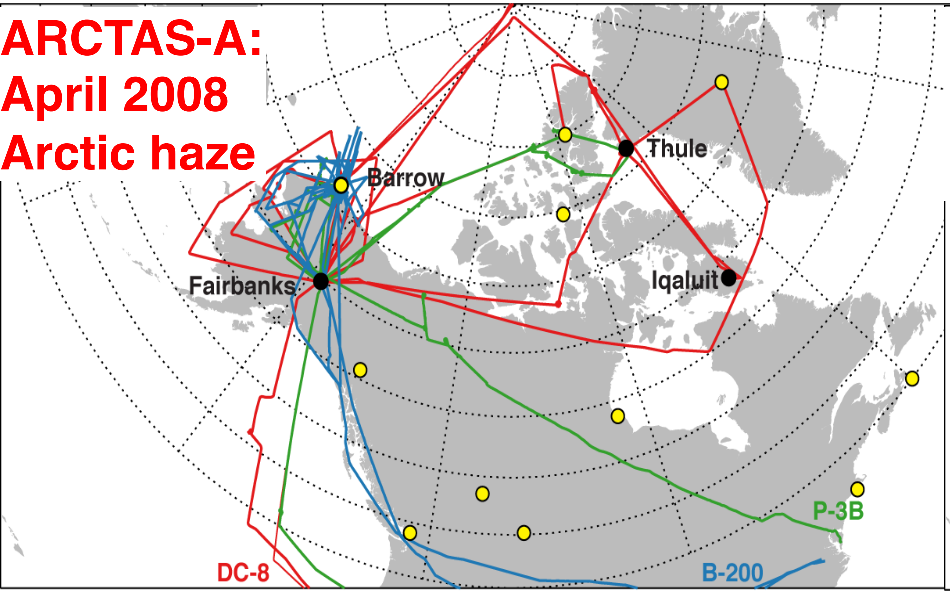
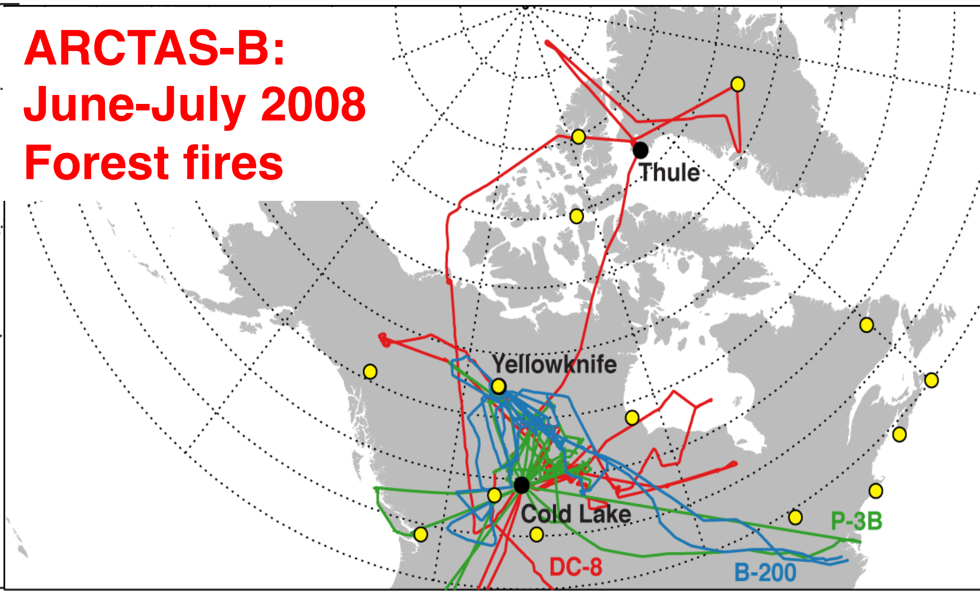
ARCTAS:
near-term climate forcers in the Arctic-Boreal Zone

Daniel J. Jacob

Harvard University
Atmospheric Chemistry Modeling Group



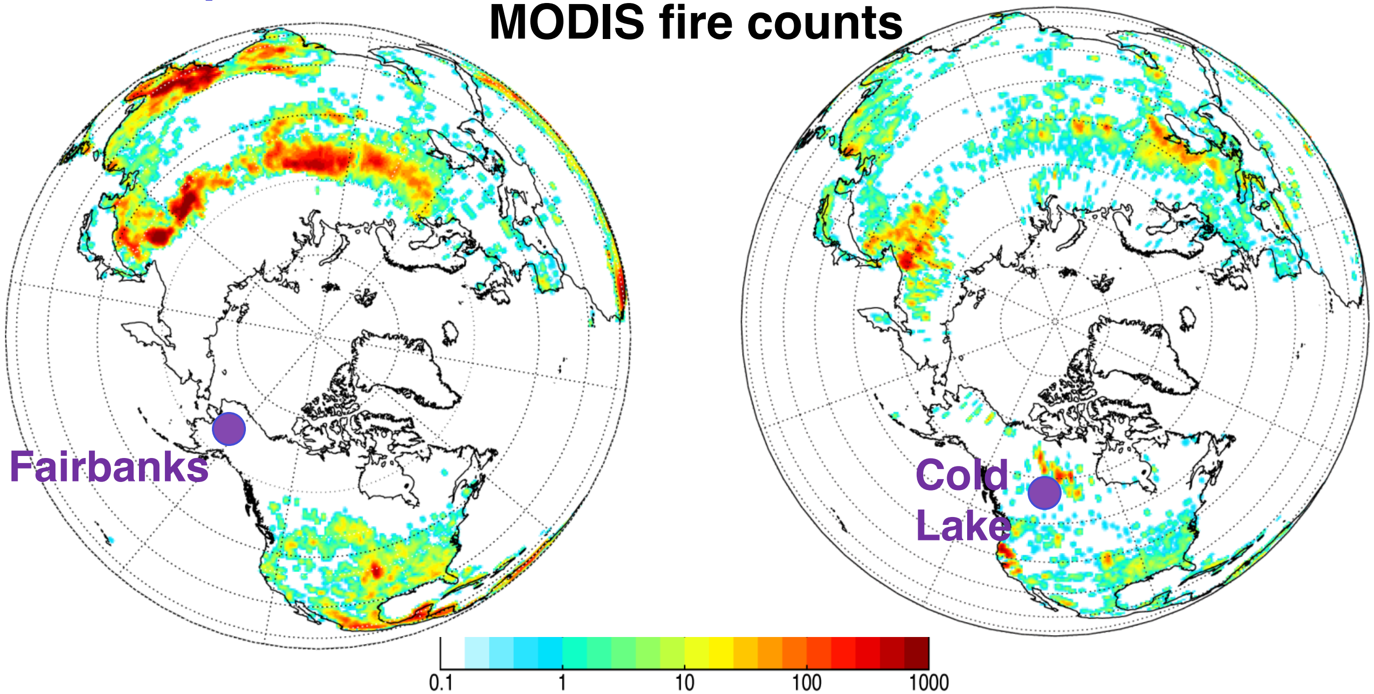


- Objective: better understand the factors driving current changes in Arctic atmospheric composition and climate
- DC-8, P-3, B-200 aircraft with payloads for atmospheric composition, aerosol properties, radiation

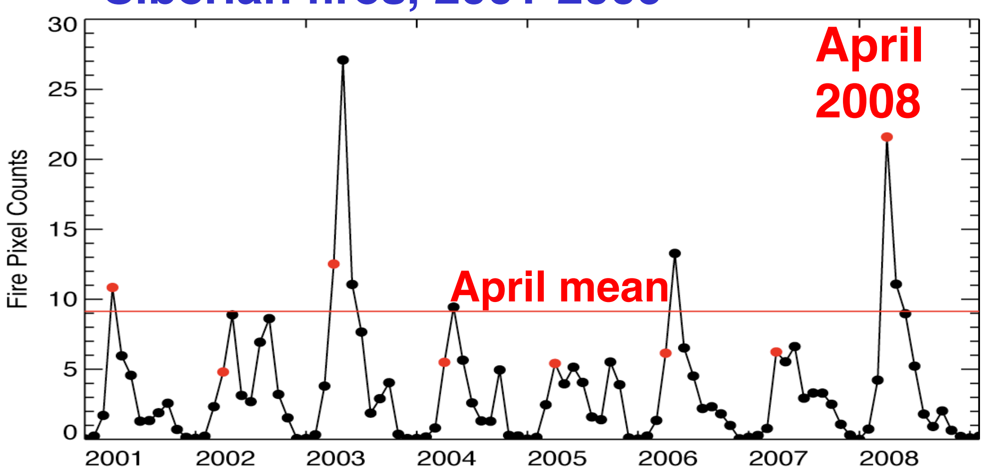
Fire influences in ARCTAS

April 2008 **July 2008**

MODIS fire counts



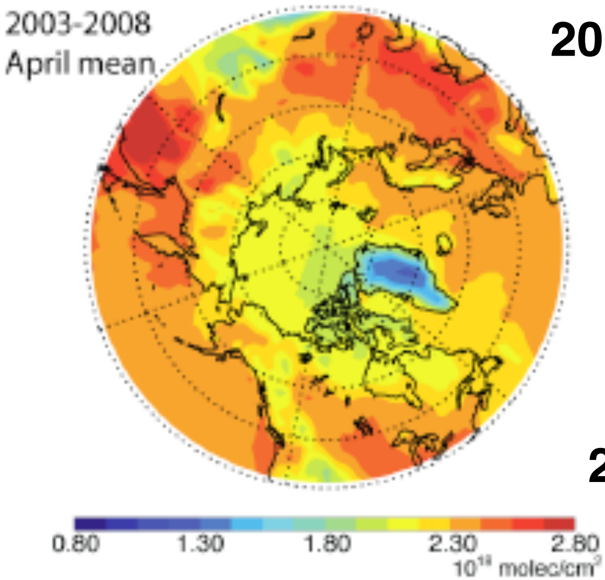
Siberian fires, 2001-2009



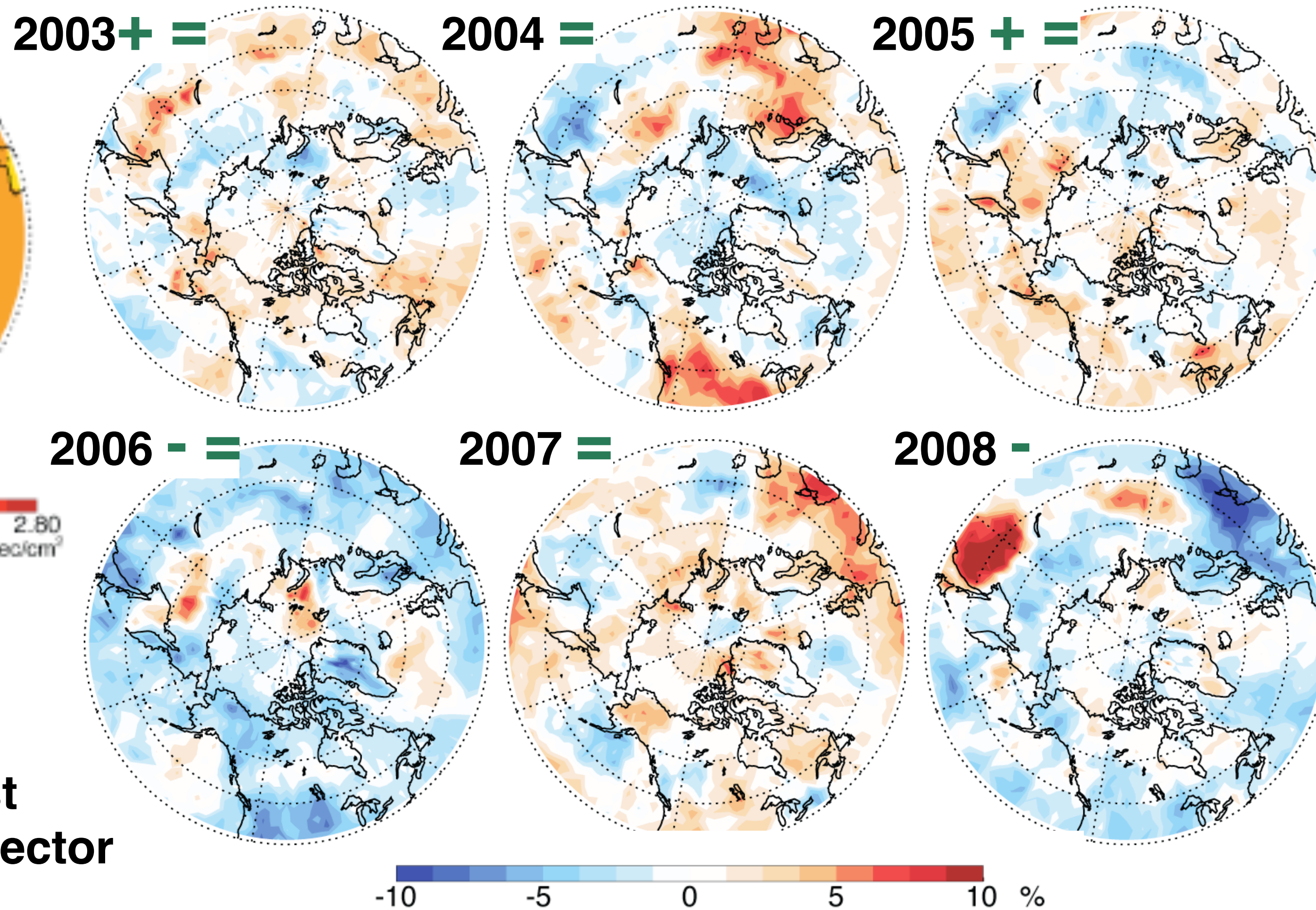
Interannual variability of Arctic spring pollution from AIRS CO

ARCTAS demonstrated value of AIRS CO for tracking plumes over the Arctic

2003-2008 April mean AIRS CO



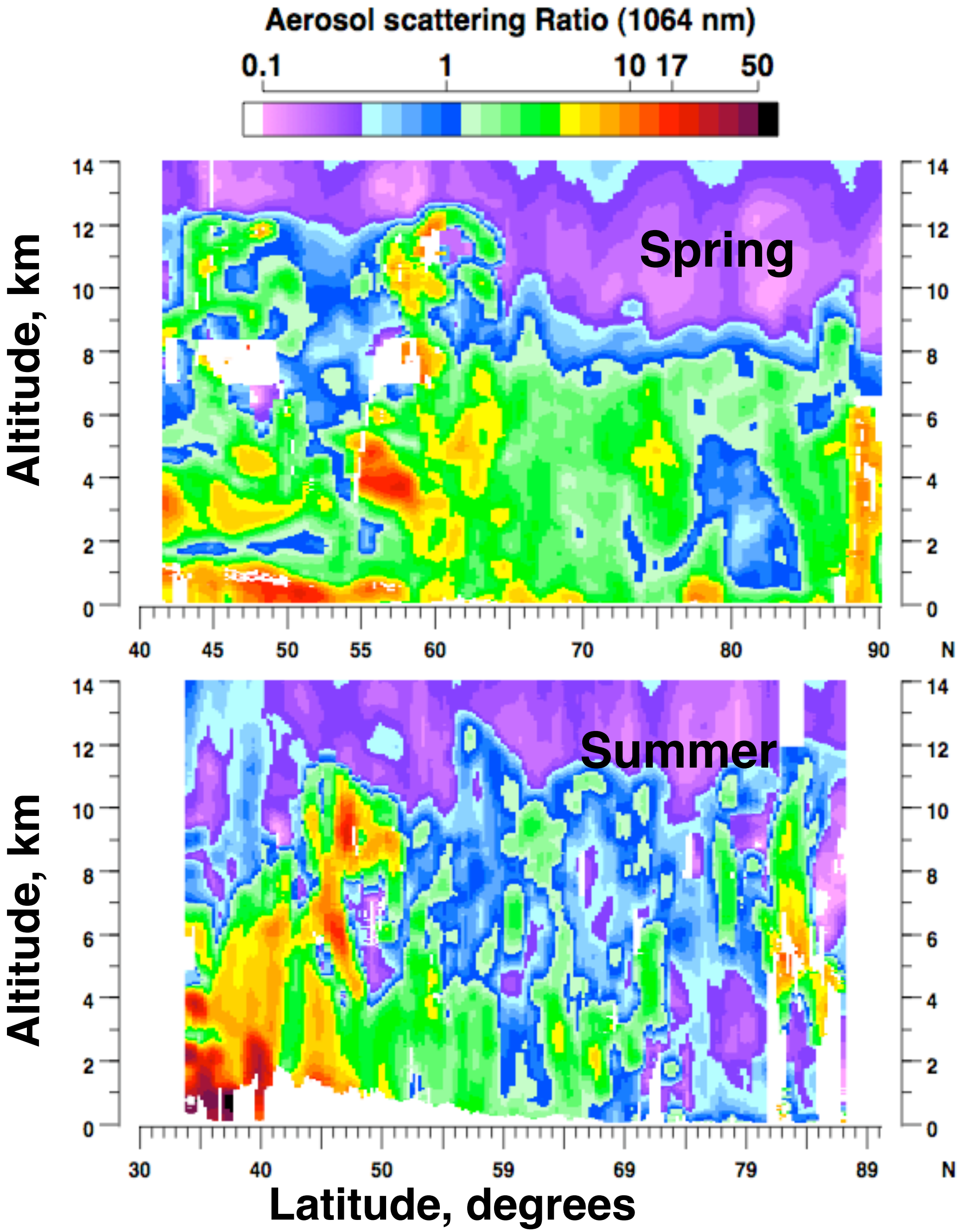
Interannual anomaly (ENSO Index)

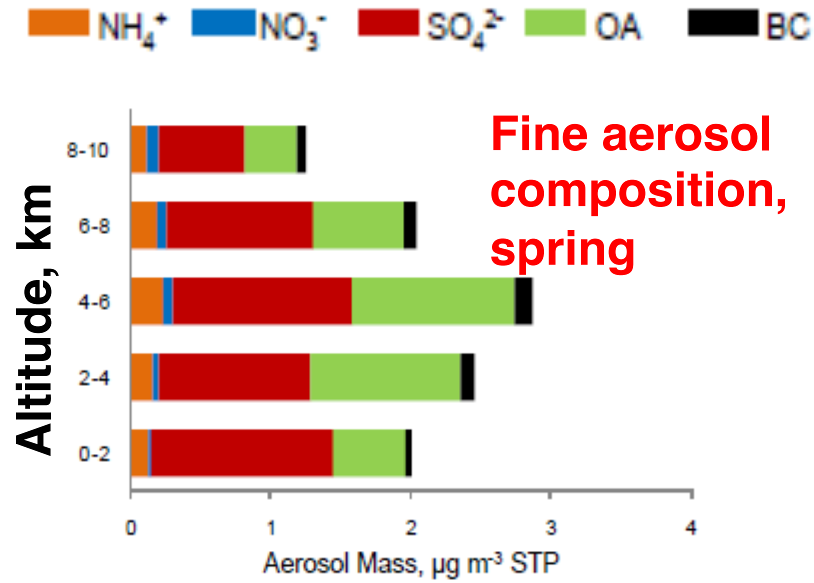


- European sector most polluted, N American sector cleanest
- Transport of Asian pollution to the Arctic is correlated with ENSO through strength of Aleutian Low

Fisher et al. [2010]

Mean aerosol altitude-latitude curtains during ARCTAS

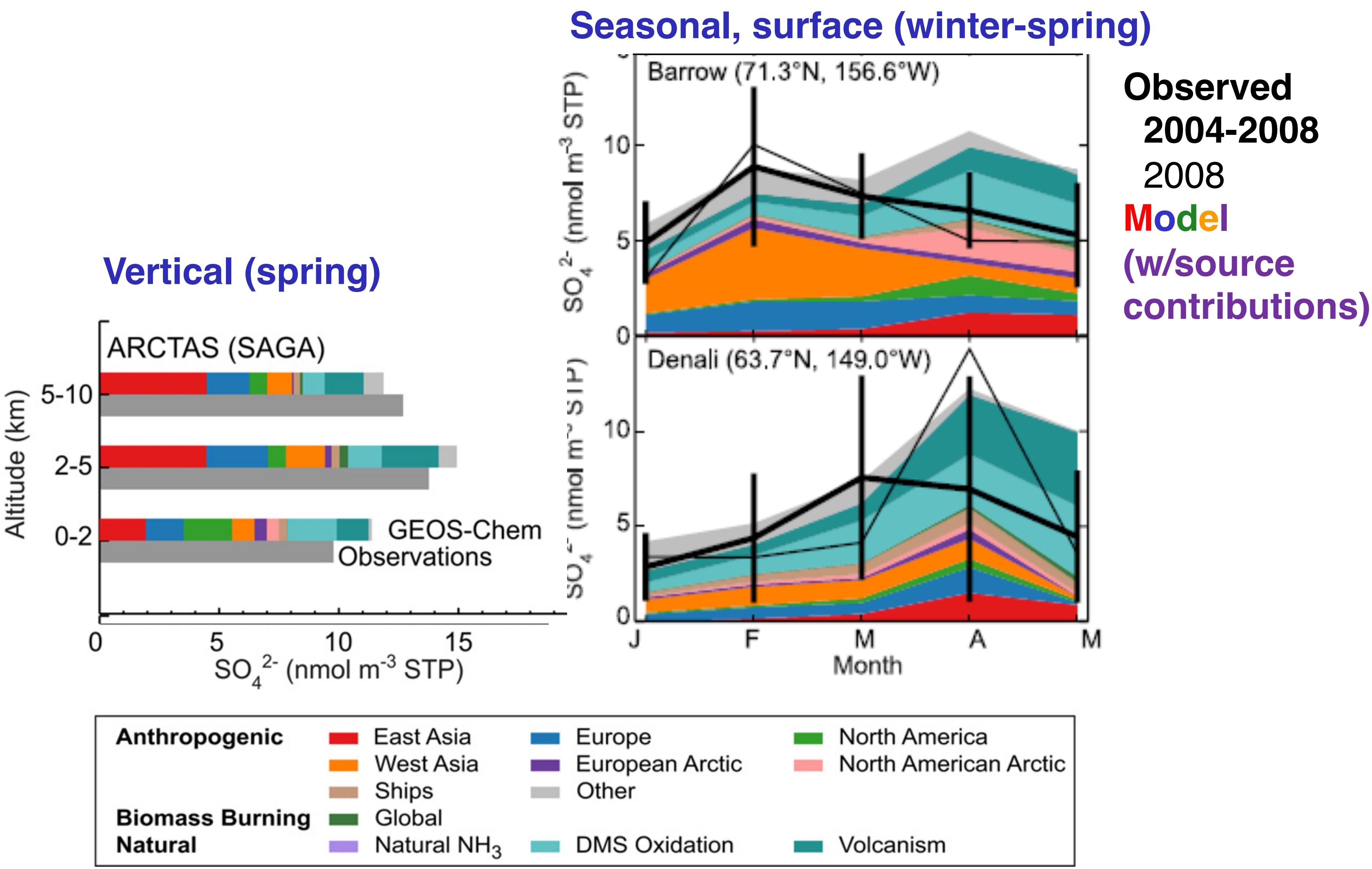




- Aerosol Is mostly sulfate and organic (OA) in spring, organic in summer
- Aerosol loading is much higher in spring than summer
- Mid-tropospheric maximum in spring

J. Hair, NASA LaRC; Wang et al. [2011]

Sources of sulfate aerosol in the Arctic



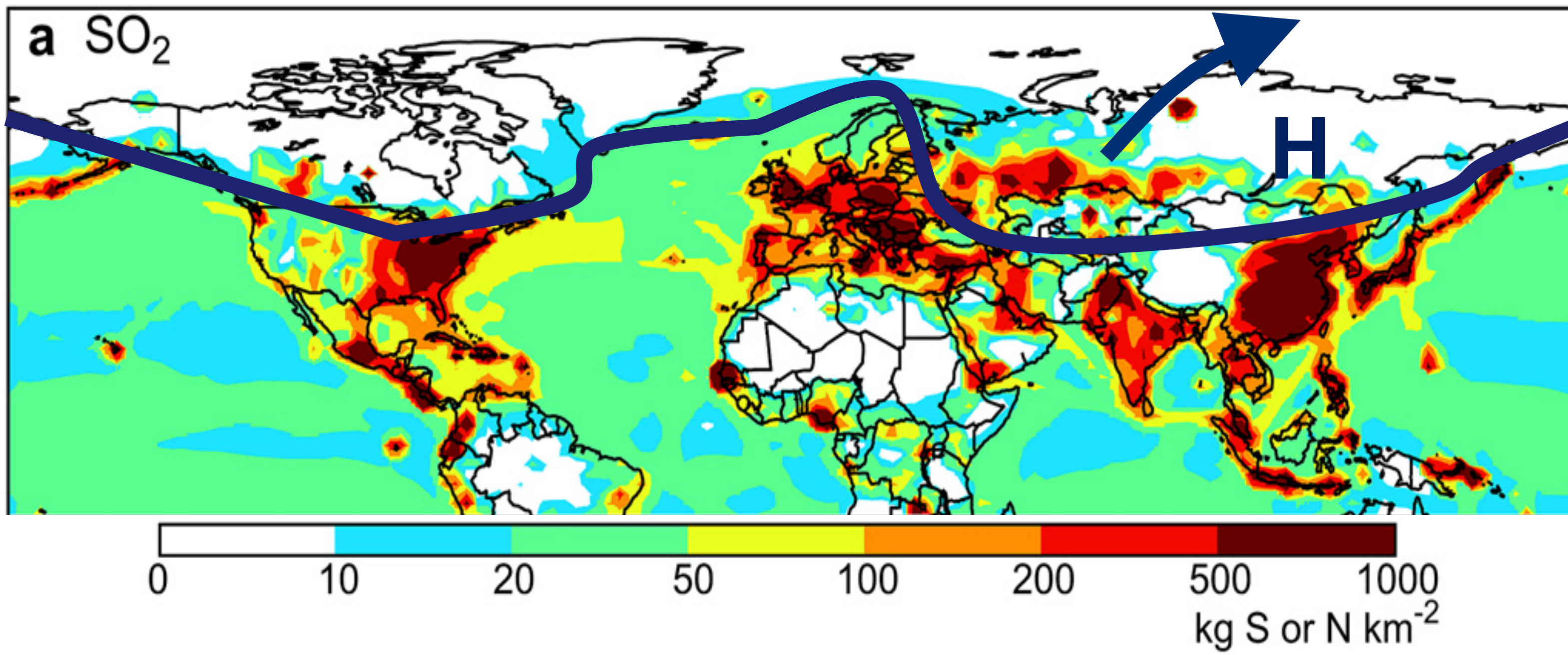
- **Mix of sources in spring at all altitudes**
- **Large Russian contribution in high Arctic in winter**

Fisher et al. [2011]

Low-altitude winter transport of Russian pollution to the Arctic

Arctic front in January [Barrie and Hoff, 1984]

GEOS-Chem SO_2 emissions, Jan-Apr 2008

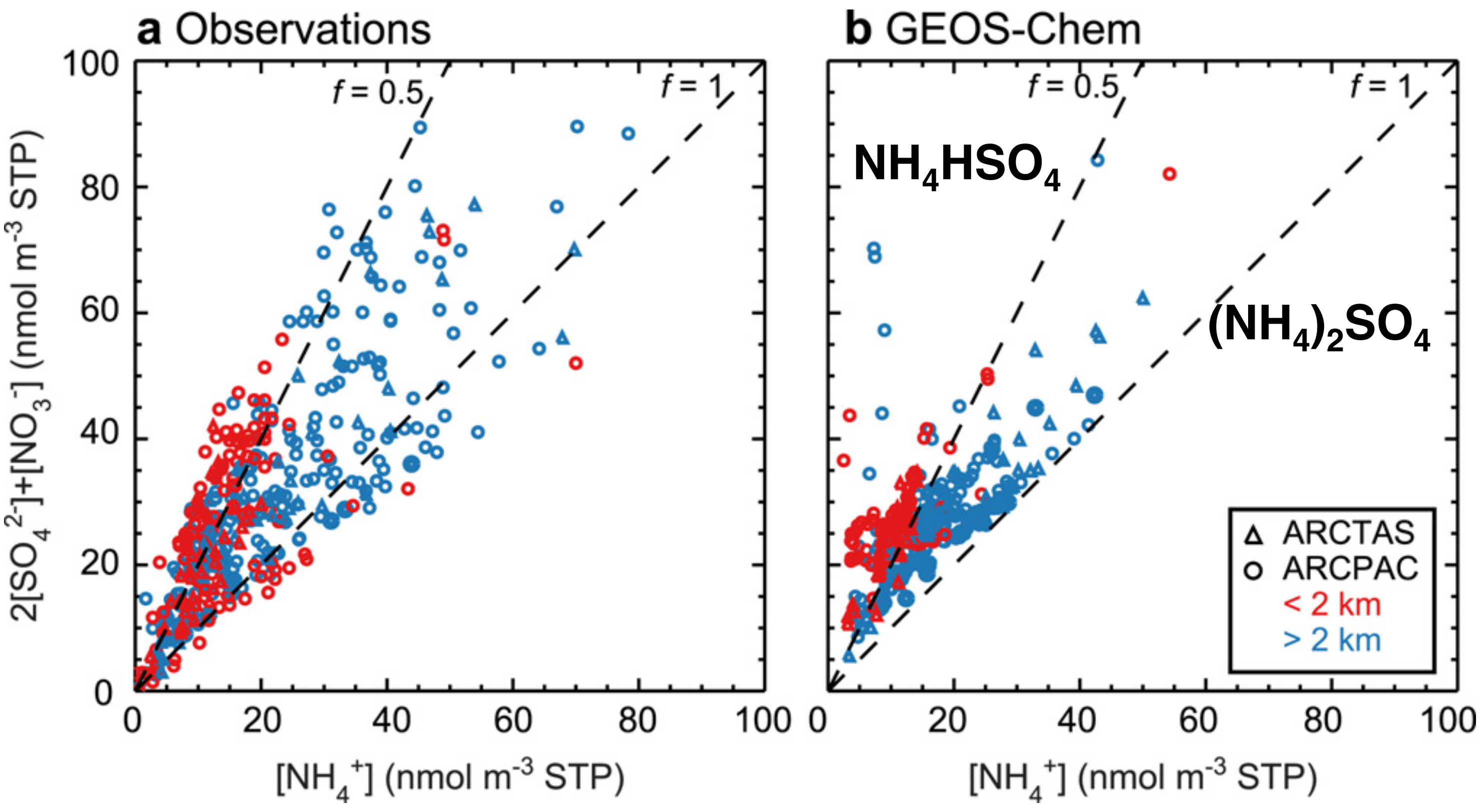


- **Emissions from Russia and Kazakhstan are readily transported to high Arctic in winter by surface circulation around Siberian High**
- **There is enough photochemistry at 40º N to allow oxidation of SO_2 to sulfate**
- **Coal/petroleum production in Russia and Kazakhstan increased by ~50% between 2000 and 2007**

Fisher et al. [2011]

Acidity of sulfate-ammonium Arctic aerosol in spring

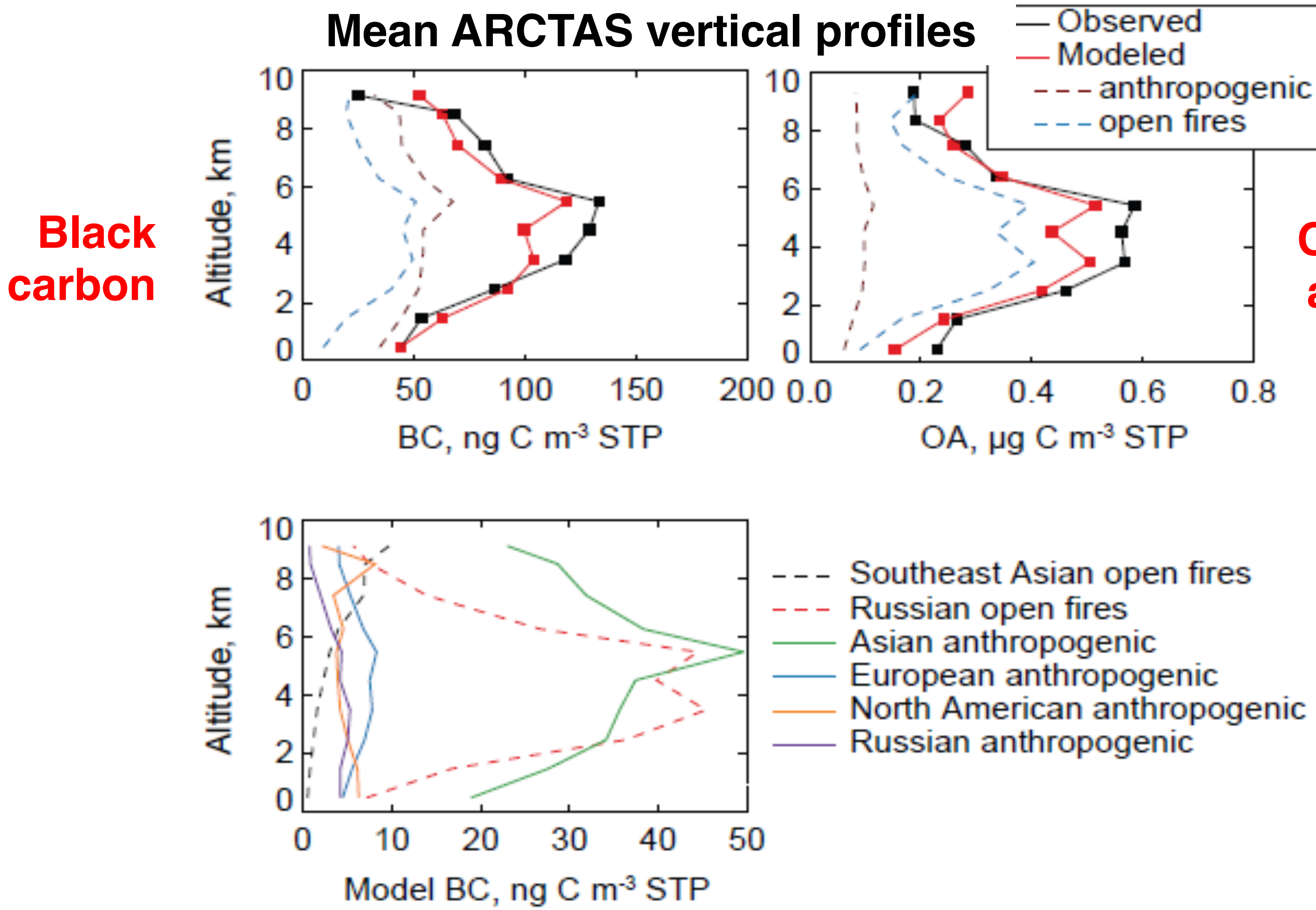
affects hygroscopicity, homogeneous freezing, ice nuclei properties



- **Arctic aerosol is generally acidic, less strongly in free troposphere**
- **Dominant sources of ammonia are from fires and Asian pollution**
- **Observed 1998-2008 increase in aerosol acidity at Barrow (Quinn et al., 2009) may reflect rising Russian source of sulfate**

Fisher et al. [2011]

Sources of carbonaceous aerosol in Arctic spring

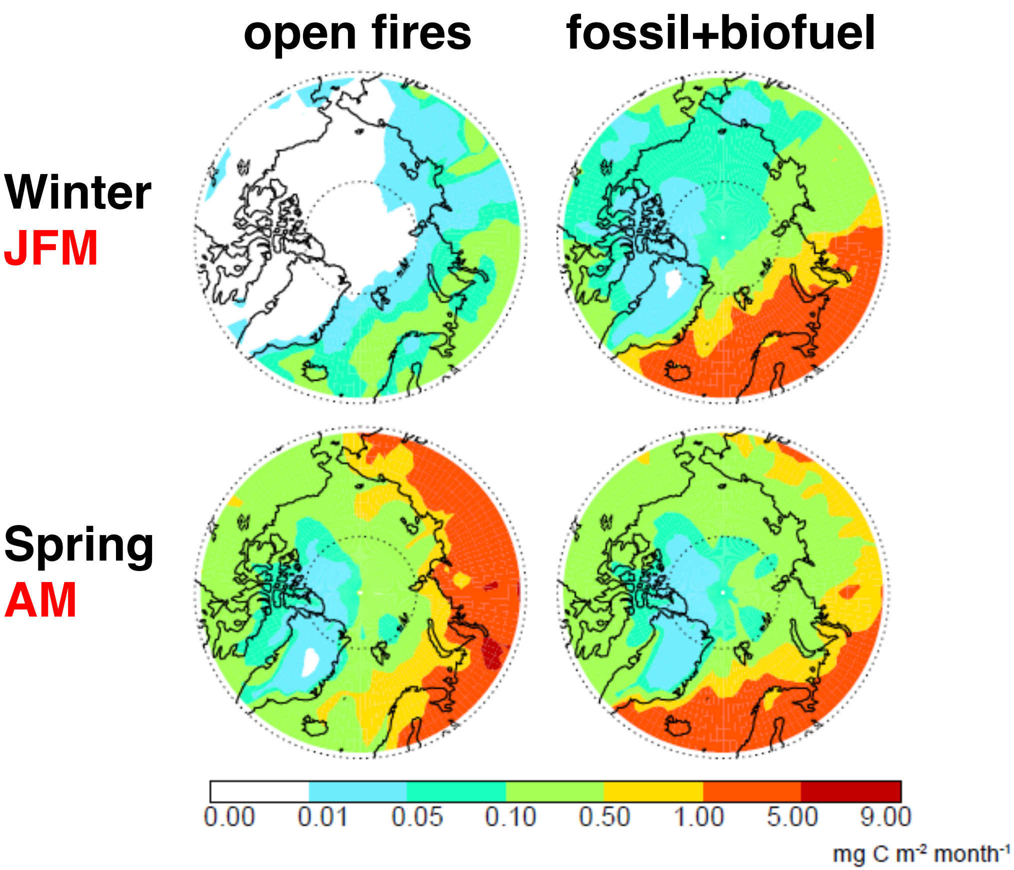


- Organic aerosol is mostly from fires (even in normal fire years)
- BC is mostly anthropogenic (even in 2008)
- Correlations with sulfate, acetonitrile confirm this source attribution

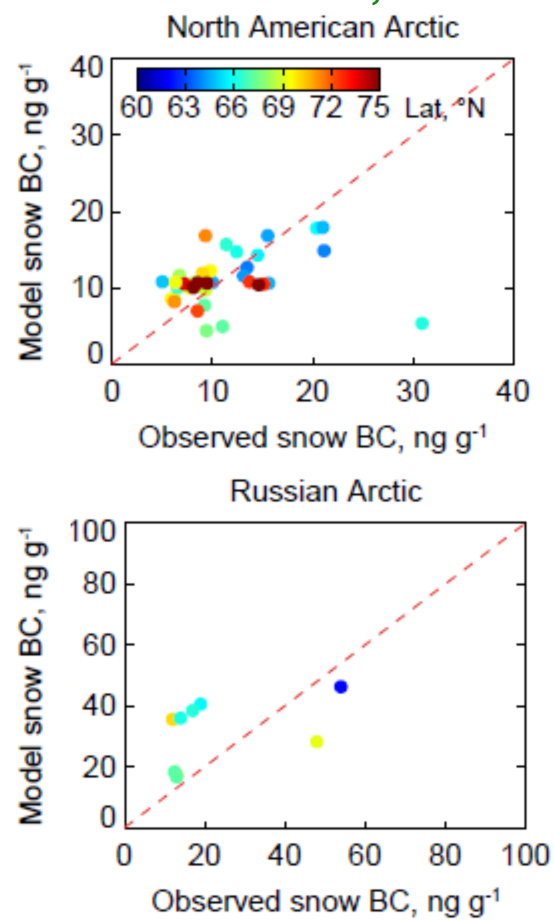
Shinozuka et al. [2010]; Wang et al. [2011]

BC deposition to snow: implications for radiative forcing

BC deposition flux in 2008 (GEOS-Chem)



Model vs. observed snow BC content, 2007-2009



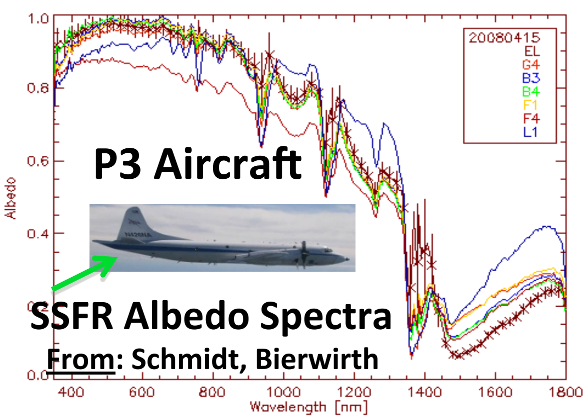
- **BC deposition is much higher in Eurasian than N. American sector**
- **Fuel sources dominate over Arctic scale (>90% in winter, 60% in spring 2007-2009)**
- **Snow albedo decrease from BC is estimated to be 0.4% (winter), 0.6% (spring)**

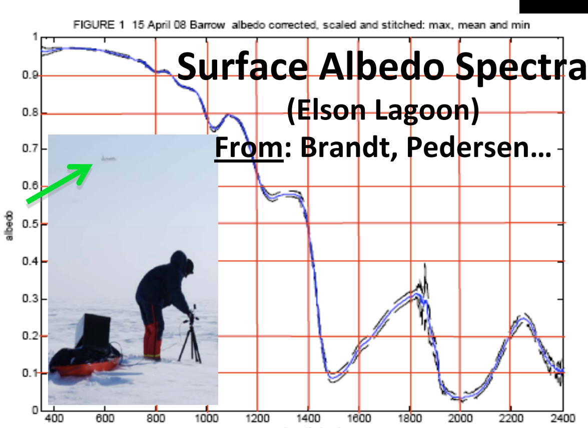
Wang et al. [2011]

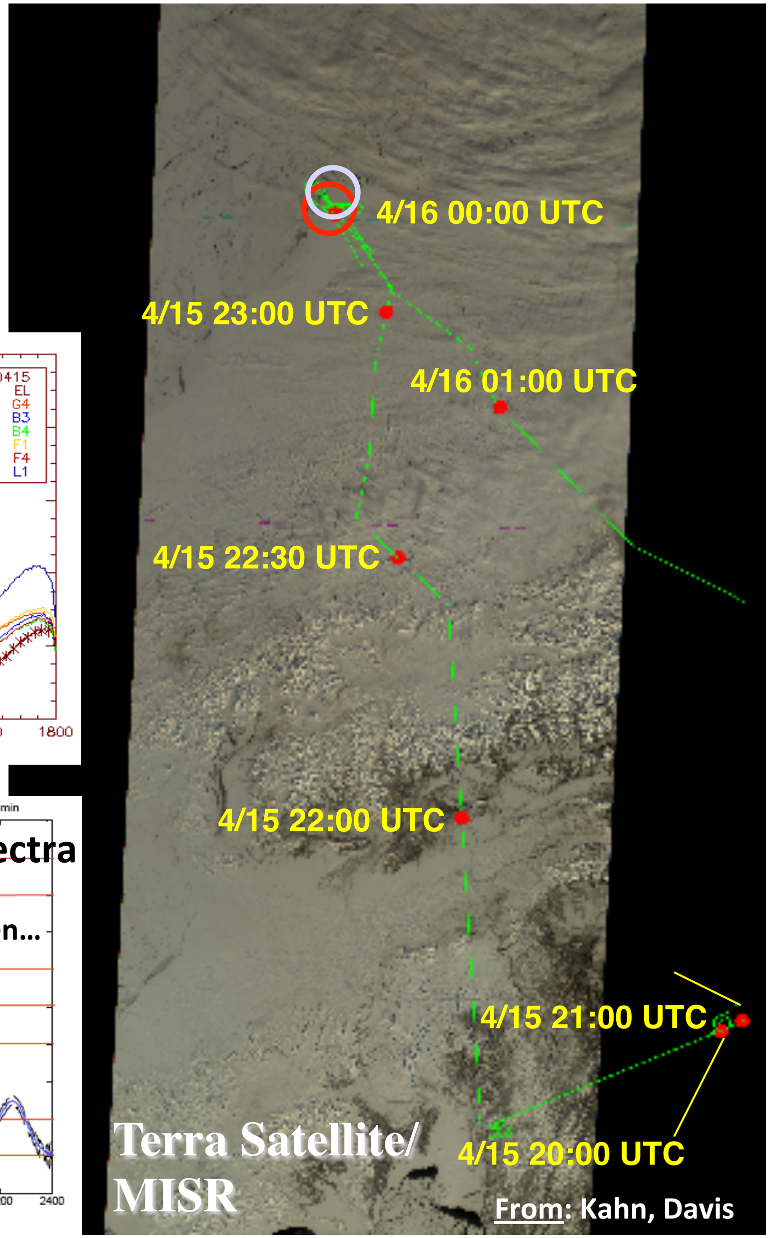
ARCTAS: Barrow/Eslon Lagoon 15 April 2008

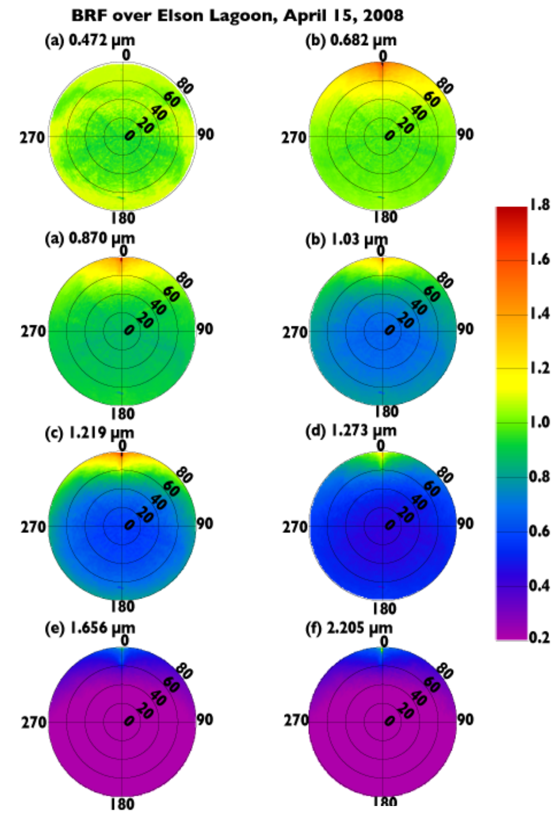
Lat 71.3˚ Lon -156.7; SZA 61.1˚ [Terra at 22:30 UTC]

Coincident
Snow Albedo & BRF from Surface, Aircraft, and Satellite
Best ever multi-scale observations









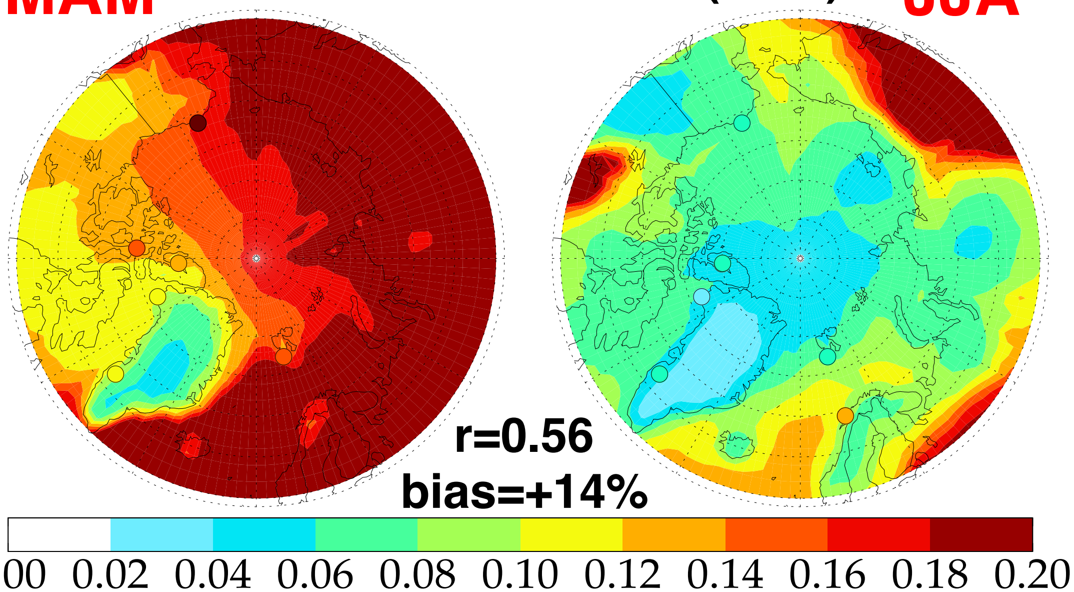
CAR Spectral BRF
From: Gatebe

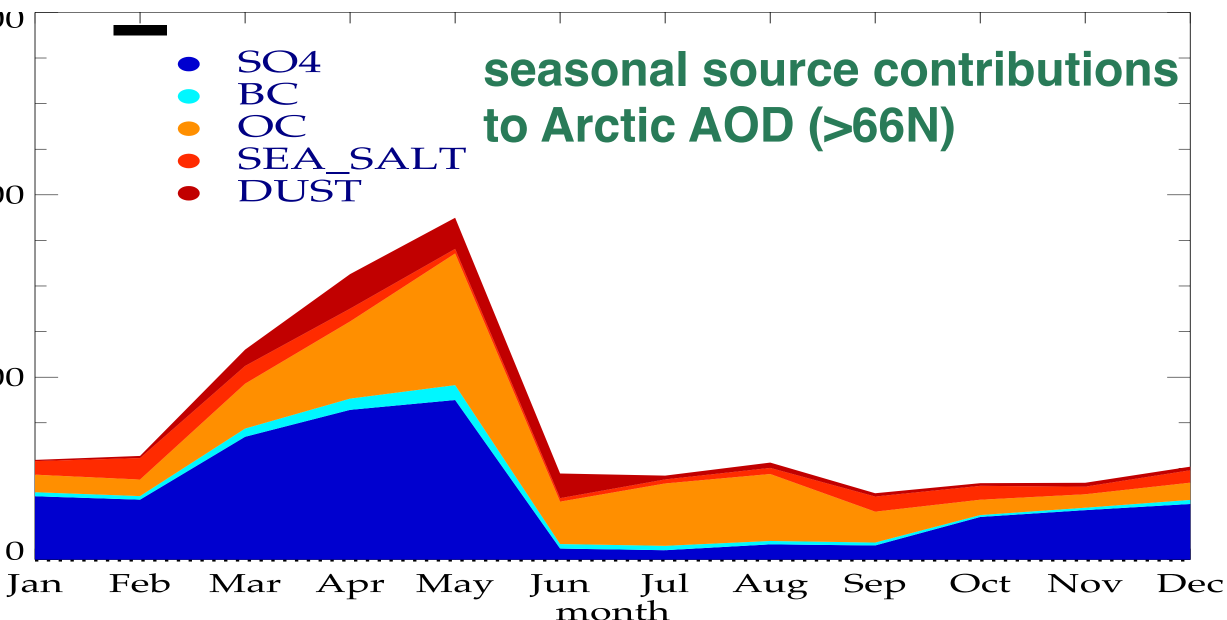
P-3 Flight Path
Barrow AERONET Site
Ground Measurements

Arctic aerosol optical depth (AOD)

contours: GEOS-Chem
circles: AERONET (2008)

MAM **JJA**





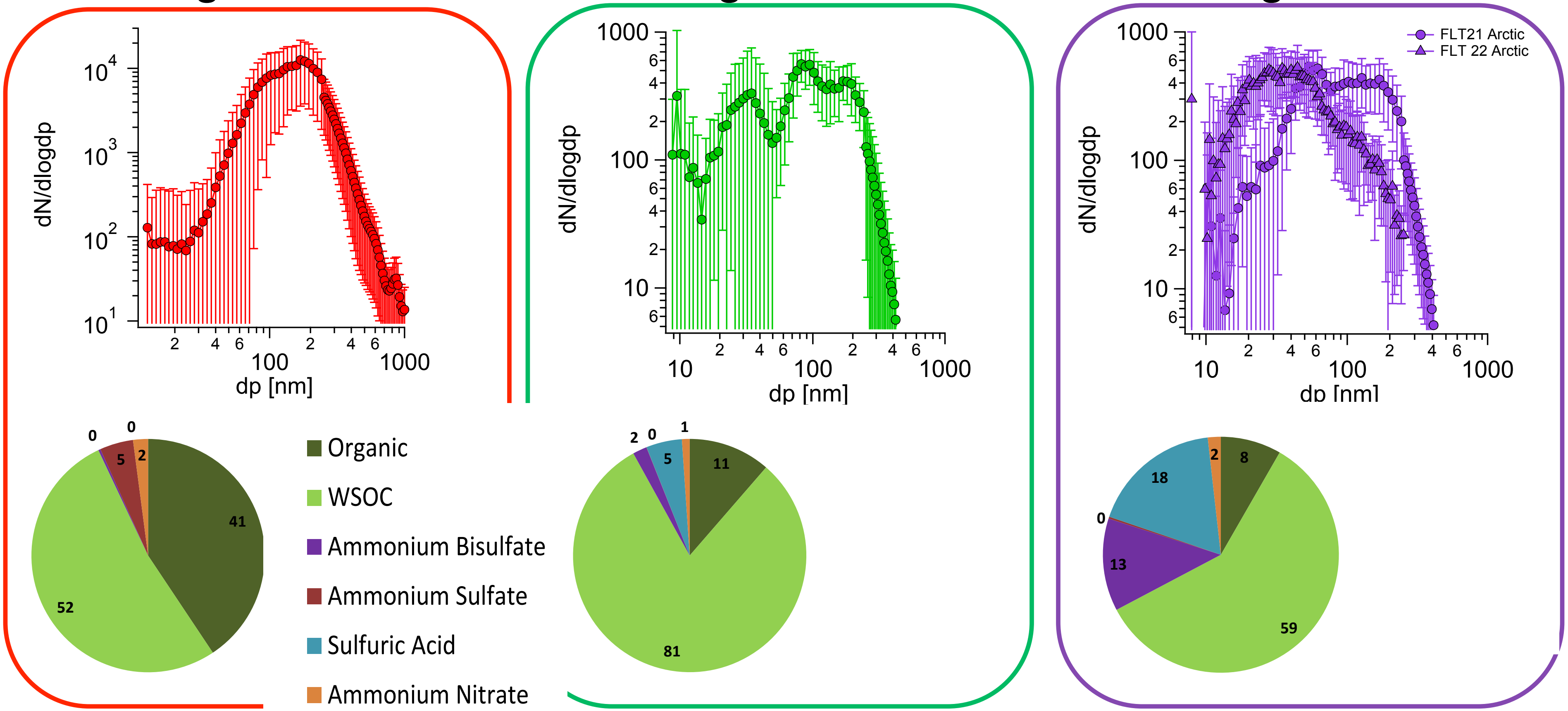
- **AOD is mostly from sulfate in spring, OC (fires) in summer**
- **Saharan dust also makes a significant contribution**
- **The large AOD decrease from spring to summer reflects in part smaller sulfate particles**

Breider et al., in prep.

Arctic aerosol Properties in summer

Mean aerosol size distribution and composition

Fresh Biomass Burning | **Boreal Forest Background** | **High Arctic Background**



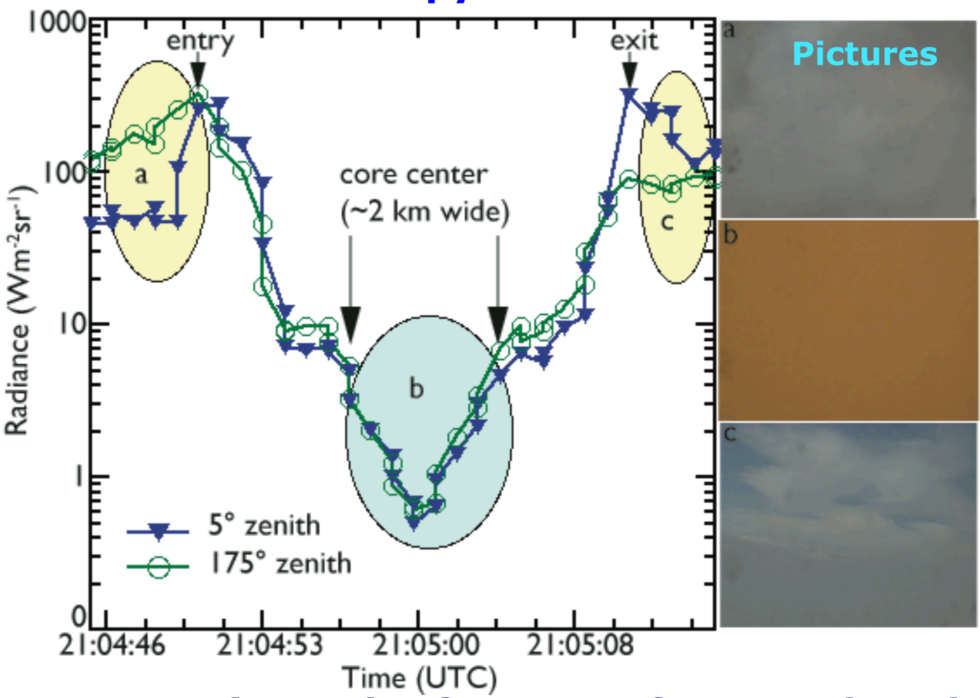
Most of the aerosol is water-soluble organic material, which is hygroscopic and effective as CCN

Lathem et al., *in prep.*

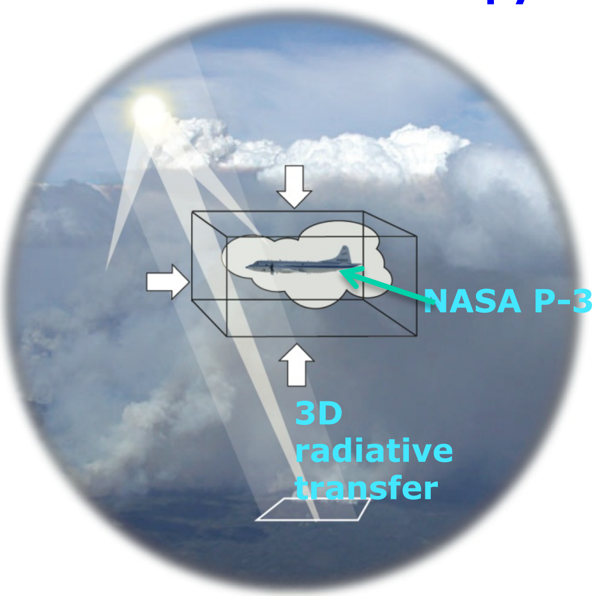
Pyrocumulus optical properties observed in ARCTAS

- **A.** Strong light extinction detected in the core of dense fire clouds (pyroCu).
- **B.** Radiation transport in pyroCu is inherently a 3D problem and must account for particle absorption. ARCTAS provide unprecedented data.
- **C.** Angular radiance distribution in dense pyroCu clouds is very complex. This study developed new simple diffusion approximations in place of 3D RT, which reproduce all angular features accurately.

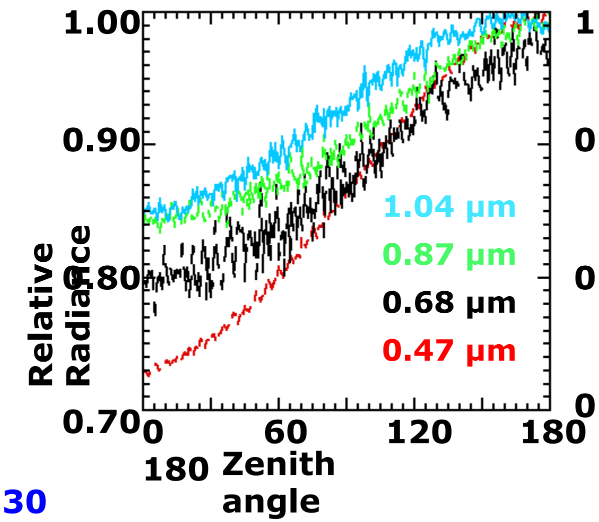
A. Transect of pyroCu

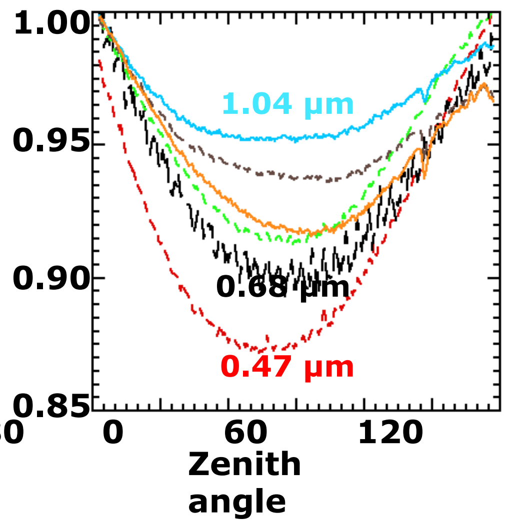


B. Radiative transfer in pyroCu



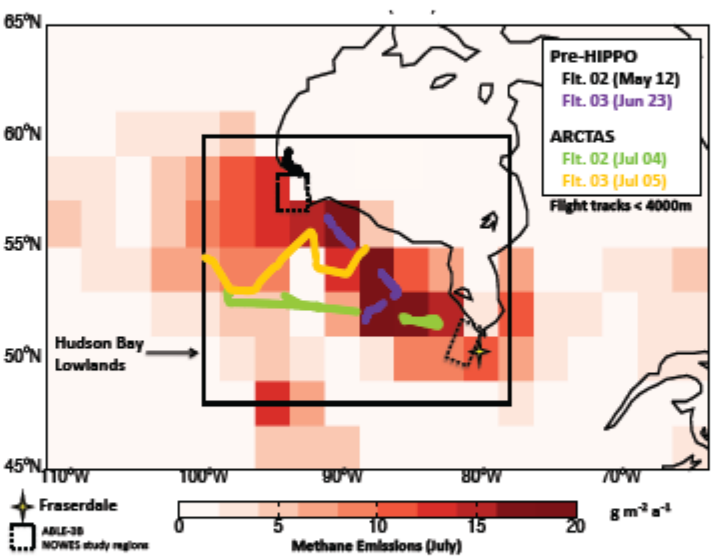
C. Spectral-angular features of pyroCu (core)

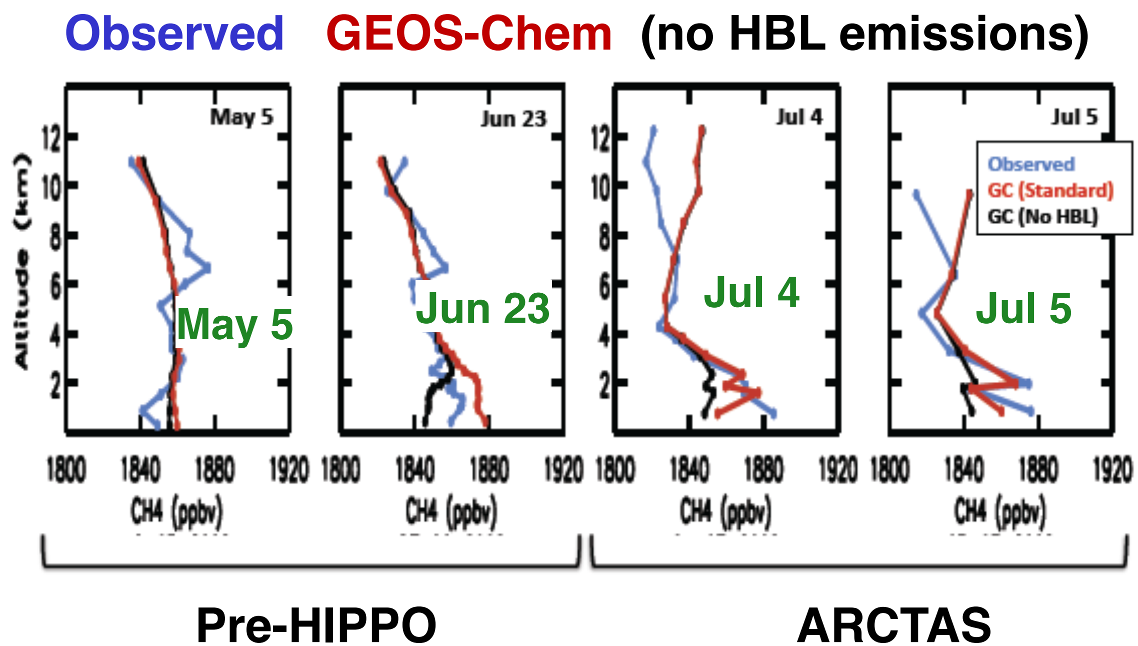




Gatebe et al 2012, Atmos. Env. 52, 121-130

Methane emissions from Hudson Bay Lowlands

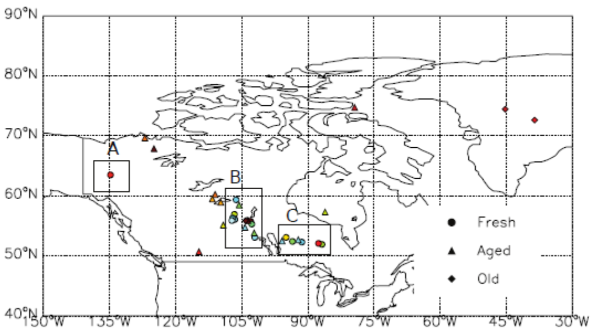


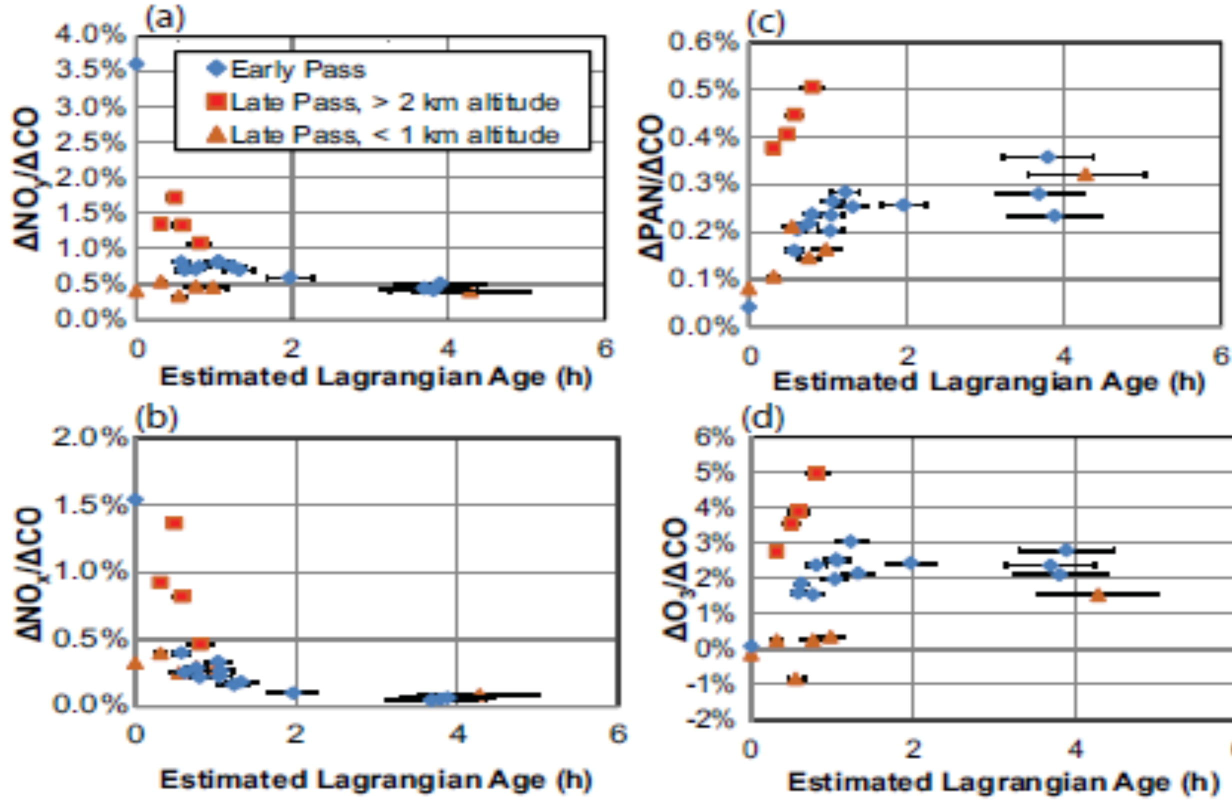


- Emission from HBL started only after snowmelt
- ARCTAS + surface (Fraserdale) constraints imply annual methane emission from HBL of 2.3 Tg a^{-1}, several-fold higher than inferred from ABLE-3B (1990)
- The ARCTAS spring deployment observed no methane enhancements anywhere

Pickett-Heaps et al. [2011]

Boreal fire plumes in ARCTAS in summer showed no significant ozone enhancement

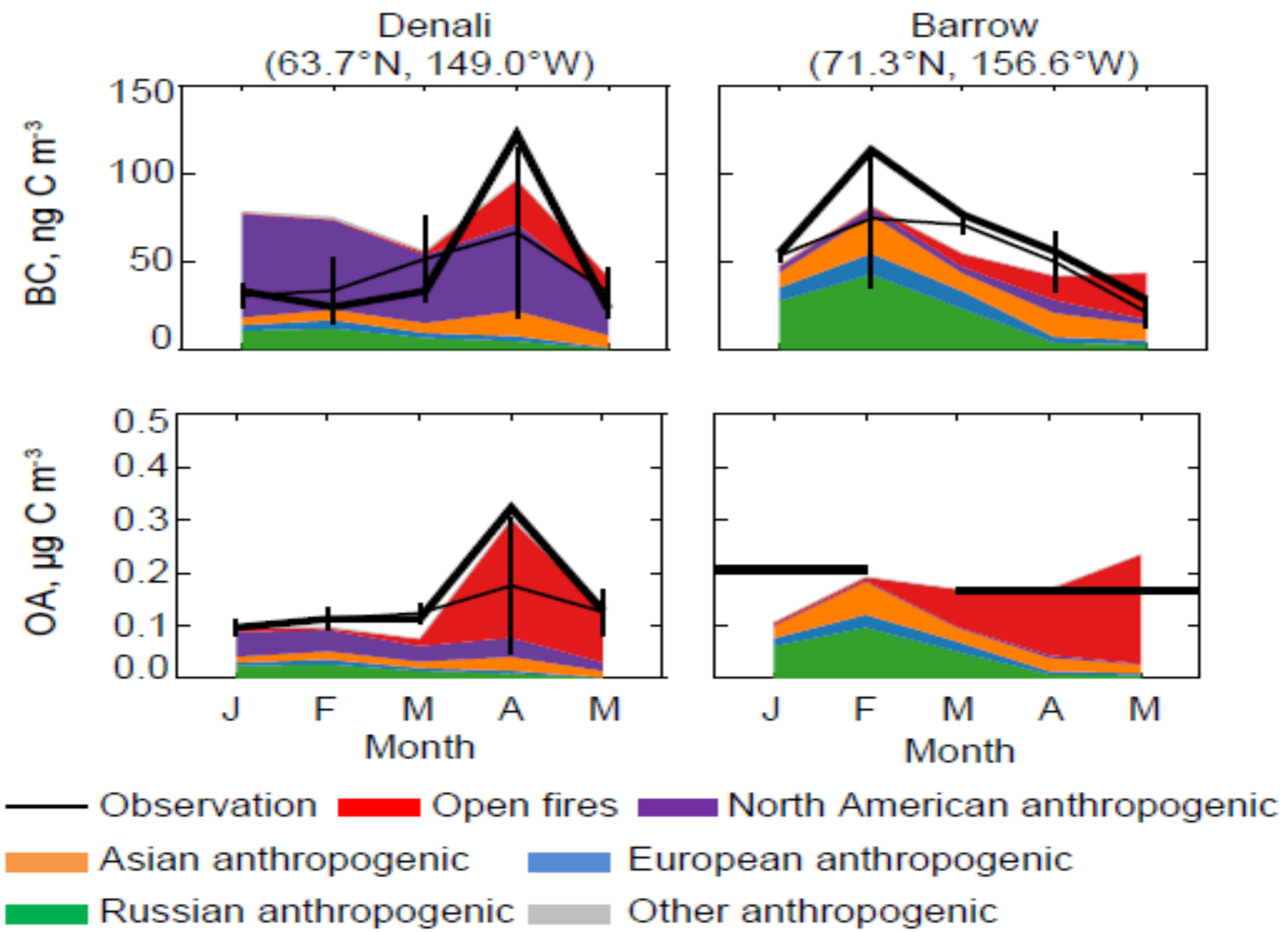


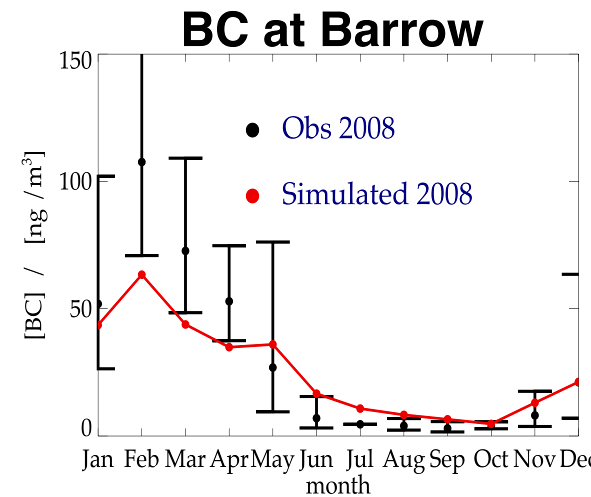


- NO_x emission from fires was lower than assumed in standard inventories
- Emitted NO_x was locked up as PAN (stable reservoir) within a few hours
- Lack of ozone enhancements was consistent withTES satellite data
- Subsequent decomposition of PAN eventually produces ozone but mostly outside the Arctic

Alvarado et al. [2010]; Hecobian et al. [2010]

Winter-spring transition in carbonaceous aerosol sources





- **As for sulfate, large difference between high and low Arctic in winter driven by Russian source**

Wang et al. [2011]; Breider et al.,in prep